CoAP and IoT

https://jaime.win/lecture/coap

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Table of Contents

1. IETF Standards
2. CoAP
3. Implementations and examples

Internet Engineering Task Force (IETF)

IETF®

The IETF mission

- IETF's role: Specify the underlying, fundamental Internet technologies
- "Permissionless innovation" - others can build on top - unlike "App Stores" or Telco services.
- RFC3935: "The goal of the IETF is to make the Internet work better."
- Some well known achievements …
  - RFC791 The Internet Protocol.
  - RFC792 The Internet Control Message Protocol.
  - RFC821 The Simple Mail Transfer Protocol.
  - RFC768 User Datagram Protocol.
  - RFC959 The File Transfer Protocol.
  - RFC793 The Transmission Control Protocol.
  - RFC854 Telnet Specification.
  - RFC1119 Network Time Protocol.
  - RFC1157 A Simple Network Management Protocol.
  - RFC1035 Domain names - implementation and specification.
  - RFC1945 Hypertext Transfer Protocol.
  - RFC2131 Dynamic Host Configuration Protocol.
  - RFC3261 The Session Initiation Protocol.
  - RFC6455 The WebSocket Protocol.
  - RFC5321 Simple Mail Transfer Protocol.
  - RFC7540 Hypertext Transfer Protocol Version 2.
  - RFC6749 The OAuth 2.0 Authorization Framework.
  - RFC4271 The Border Gateway Protocol.
  - RFC4287 The Atom Syndication Format.
  - RFC4251 The Secure Shell (SSH) Protocol Architecture.
  - RFC8200 Internet Protocol, Version 6 (IPv6) Sepcification.

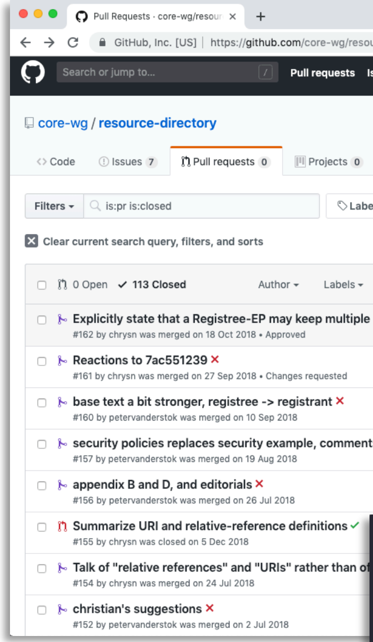
”Rough consensus and running code"

Ways of working: RD Example

Working on the draft
https://github.com/core-wg/resource-directory

Working on the code
https://github.com/thomas-fossati/gordo

Other examples
https://github.com/Ell-i/coap-rd
https://github.com/nning/core-rd



core-wg / resource-directory

is:pr is:closed

☒ Clear current search query, filters, and sorts

□ 0 Open ✓ 113 Closed

□ Explicitly state that a Registree-EP may keep multiple registra
#162 by chrysn was merged on 18 Oct 2018 • Approved

□ Reactions to 7ac551239 ✗
#161 by chrysn was merged on 27 Sep 2018 • Changes requested

□ base text a bit stronger, registree -> registrant ✗
#160 by petervanderstok was merged on 10 Sep 2018

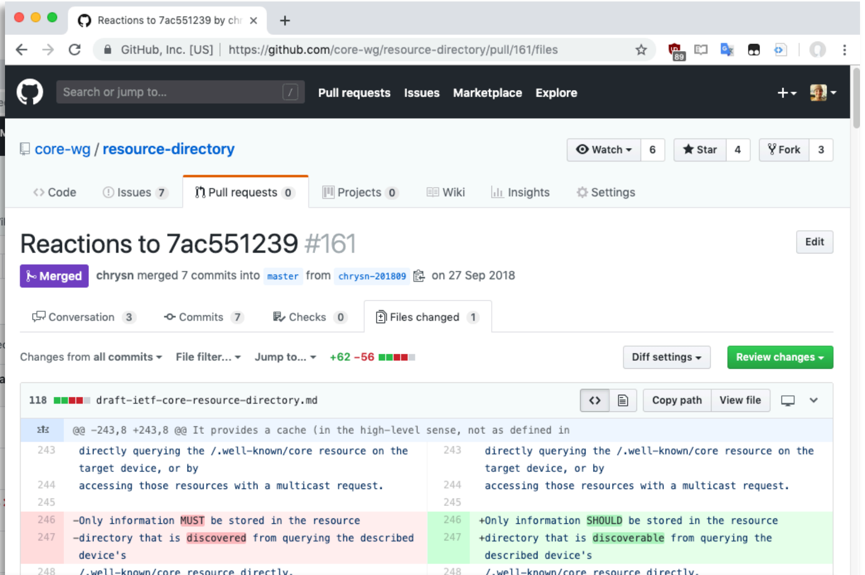
□ security policies replaces security example, comments jaime
#157 by petervanderstok was merged on 19 Aug 2018

□ appendix B and D, and editorials ✗
#156 by petervanderstok was merged on 26 Jul 2018

□ Summarize URI and relative-reference definitions ✓
#155 by chrysn was closed on 5 Dec 2018

□ Talk of "relative references" and "URIs" rather than of
#154 by chrysn was merged on 24 Jul 2018

□ christian's suggestions ✗
#152 by petervanderstok was merged on 2 Jul 2018



core-wg / resource-directory

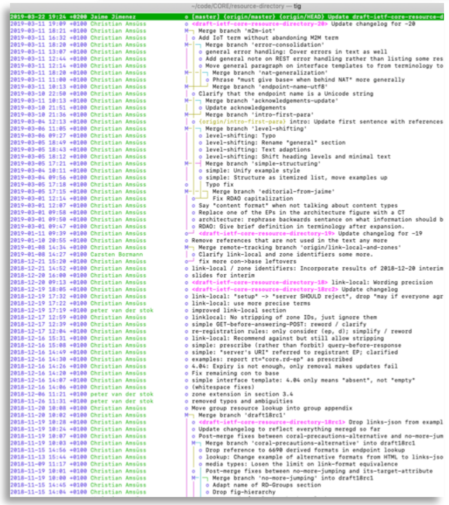
Reactions to 7ac551239 #161

Merged chrysn merged 7 commits into `master` from `chrysn-201809` on 27 Sep 2018

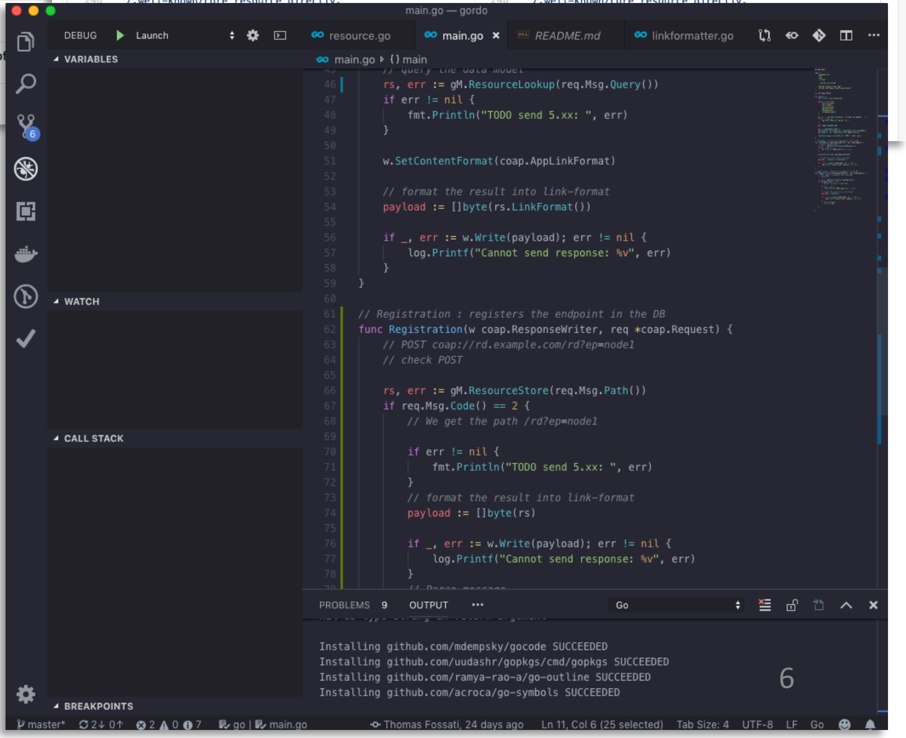
+62 −56

118 draft-ietf-core-resource-directory.md

```
@@ -243,8 +243,8 @@ It provides a cache (in the high-level sense, not as defined in
243  directly querying the /.well-known/core resource on the     243  directly querying the /.well-known/core resource on the
     target device, or by                                             target device, or by
244  accessing those resources with a multicast request.         244  accessing those resources with a multicast request.
245                                                              245
246 -Only information MUST be stored in the resource              246 +Only information SHOULD be stored in the resource
247 -directory that is discovered from querying the described     247 +directory that is discoverable from querying the
     device's                                                         described device's
248  /.well-known/core resource directly.                        248  /.well-known/core resource directly.
```


~/code/CORE/resource-directory — tig

```
2019-03-22 19:24 +0200 Jaime Jimenez        o [master] {origin/master} {origin/HEAD} Update draft-ietf-core-resource-d
2019-03-11 19:09 +0100 Christian Amsüss     o <draft-ietf-core-resource-directory-20> Update changelog for -20
2019-03-11 18:21 +0100 Christian Amsüss     M─┐ Merge branch 'm2m-iot'
2019-03-11 16:32 +0100 Christian Amsüss     │ o Add IoT term without abandoning M2M term
2019-03-11 18:20 +0100 Christian Amsüss     M─│─┐ Merge branch 'error-consolidation'
2019-03-11 13:07 +0100 Christian Amsüss     │ │ o general error handling: Cover errors in text as well
2019-03-11 12:44 +0100 Christian Amsüss     │ │ o Add general note on REST error handling rather than listing some res
2019-03-11 12:14 +0100 Christian Amsüss     │ │ o Move general paragraph on interface templates to from terminology to
2019-03-11 18:20 +0100 Christian Amsüss     M─│─│─┐ Merge branch 'nat-generalization'
2019-03-11 11:00 +0100 Christian Amsüss     │ │ │ o Phrase "must give base= when behind NAT" more generally
2019-03-11 10:13 +0100 Christian Amsüss     M─┴─┴─┘ Merge branch 'endpoint-name-utf8'
2019-03-10 22:50 +0100 Christian Amsüss     │ o Clarify that the endpoint name is a Unicode string
2019-03-11 10:13 +0100 Christian Amsüss     M─│─┐ Merge branch 'acknowledgements-update'
2019-03-10 21:51 +0100 Christian Amsüss     │ │ o Update acknowledgements
2019-03-10 21:36 +0100 Christian Amsüss     M─┴─┘ Merge branch 'intro-first-para'
2019-03-04 12:13 +0100 Christian Amsüss     │ o {origin/intro-first-para} intro: Update first sentence with references
2019-03-06 11:05 +0100 Christian Amsüss     M─│─┐ Merge branch 'level-shifting'
2019-03-06 09:27 +0100 Christian Amsüss     │ │ o level-shifting: Typo
2019-03-05 18:49 +0100 Christian Amsüss     │ │ o level-shifting: Rename "general" section
2019-03-05 18:43 +0100 Christian Amsüss     │ │ o level-shifting: Text adaptions
2019-03-05 18:12 +0100 Christian Amsüss     │ │ o level-shifting: Shift heading levels and minimal text
2019-03-05 17:21 +0100 Christian Amsüss     M─│─┤ Merge branch 'simple-structuring'
2019-03-04 10:11 +0100 Christian Amsüss     │ │ o simple: Unify example style
2019-03-04 09:56 +0100 Christian Amsüss     │ │ o simple: Structure as itemized list, move examples up
2019-03-05 17:18 +0100 Christian Amsüss     o │ │ Typo fix
2019-03-05 17:15 +0100 Christian Amsüss     M─│─│─┐ Merge branch 'editorial-from-jaime'
2019-03-01 12:14 +0100 Christian Amsüss     │ o─┴─┘ Fix RDAO capitalization
2019-03-01 12:07 +0100 Christian Amsüss     │ o Say "content format" when not talking about content types
2019-03-01 09:58 +0100 Christian Amsüss     │ o Replace one of the EPs in the architecture figure with a CT
2019-03-01 09:50 +0100 Christian Amsüss     │ o architecture: rephrase backwards sentance on what information should b
2019-03-01 09:47 +0100 Christian Amsüss     │ o RDAO: Give brief definition in terminology after expansion.
2019-01-11 09:39 +0100 Christian Amsüss     o─┘ <draft-ietf-core-resource-directory-19> Update changelog for -19
2019-01-10 20:55 +0100 Christian Amsüss     o Remove references that are not used in the text any more
2019-01-08 14:34 +0100 Christian Amsüss     M─┐ Merge remote-tracking branch 'origin/link-local-and-zones'
2019-01-08 14:27 +0100 Carsten Bormann      │ o Clarify link-local and zone identifiers some more.
2018-12-21 15:20 +0100 Christian Amsüss     o─┘ fix more con->base leftovers
2018-12-21 14:52 +0100 Christian Amsüss     o link-local / zone identifiers: Incorporate results of 2018-12-20 interim
2018-12-20 16:00 +0100 Christian Amsüss     o slides for interim
2018-12-20 09:13 +0100 Christian Amsüss     o <draft-ietf-core-resource-directory-18> link-local: Wording precision
2018-12-19 18:05 +0100 Christian Amsüss     o <draft-ietf-core-resource-directory-18rc2> Update changelog
2018-12-19 17:32 +0100 Christian Amsüss     o link-local: "setup" -> "server SHOULD reject", drop "may if everyone agr
2018-12-19 17:22 +0100 Christian Amsüss     o link-local: use more precise terms
2018-12-19 17:19 +0100 peter van der stok   o improved link-local section
2018-12-17 12:59 +0100 Christian Amsüss     o linklocal: No stripping of zone IDs, just ignore them
2018-12-17 12:39 +0100 Christian Amsüss     o simple GET-before-answering-POST: reword / clarify
2018-12-17 12:04 +0100 Christian Amsüss     o re-registration rules: only consider (ep, d); simplify / reword
2018-12-16 15:31 +0100 Christian Amsüss     o link-local: Recommend against but still allow stripping
2018-12-16 15:08 +0100 Christian Amsüss     o simple: prescribe (rather than forbit) query-before-response
2018-12-16 14:49 +0100 Christian Amsüss     o simple: "server's URI" referred to registrant EP; clarified
2018-12-16 14:30 +0100 Christian Amsüss     o examples: report rt="core.rd-ep" as prescribed
2018-12-16 14:26 +0100 Christian Amsüss     o 4.04: Expiry is not enough, only removal makes updates fail
2018-12-16 14:20 +0100 Christian Amsüss     o Fix remaining con to base
2018-12-16 14:07 +0100 Christian Amsüss     o simple interface template: 4.04 only means "absent", not "empty"
2018-12-16 14:06 +0100 Christian Amsüss     o (whitespace fixes)
2018-12-06 11:21 +0100 peter van der stok   o zone extension in section 3.4
2018-11-26 11:31 +0100 peter van der stok   o removed typos and ambiguities
2018-11-20 10:08 +0100 Christian Amsüss     o Move group resource lookup into group appendix
2018-11-20 10:02 +0100 Christian Amsüss     M─┐ Merge branch 'draft18rc1'
2018-11-19 10:28 +0100 Christian Amsüss     │ o <draft-ietf-core-resource-directory-18rc1> Drop links-json from exampl
2018-11-19 10:24 +0100 Christian Amsüss     │ o Update changelog to reflect everything meregd so far
2018-11-19 10:07 +0100 Christian Amsüss     │ o Post-merge fixes between coral-precautions-alternative and no-more-jum
2018-11-19 10:03 +0100 Christian Amsüss     │ M─┐ Merge branch 'coral-precautions-alternative' into draft18rc1
2018-11-15 14:56 +0100 Christian Amsüss     │ │ o Drop reference to 6690 derived formats in endpoint lookup
2018-11-13 15:44 +0100 Christian Amsüss     │ │ o lookup: Change example of alternative formats from HTML to links-jso
2018-11-09 11:17 +0100 Christian Amsüss     │ │ o media types: Losen the limit on link-format equivalence
2018-11-19 10:01 +0100 Christian Amsüss     │ o │ Post-merge fixes between no-more-jumping and its-target-attribute
2018-11-19 10:00 +0100 Christian Amsüss     │ M─│─┐ Merge branch 'no-more-jumping' into draft18rc1
2018-11-15 14:45 +0100 Christian Amsüss     │ │ │ o Adapt name of RD-Groups section
2018-11-15 14:04 +0100 Christian Amsüss     │ │ │ o Drop fig-hierarchy
```



```go
        rs, err := gM.ResourceLookup(req.Msg.Query())
        if err != nil {
            fmt.Println("TODO send 5.xx: ", err)
        }

        w.SetContentFormat(coap.AppLinkFormat)

        // format the result into link-format
        payload := []byte(rs.LinkFormat())

        if _, err := w.Write(payload); err != nil {
            log.Printf("Cannot send response: %v", err)
        }
    }

    // Registration : registers the endpoint in the DB
    func Registration(w coap.ResponseWriter, req *coap.Request) {
        // POST coap://rd.example.com/rd?ep=node1
        // check POST

        rs, err := gM.ResourceStore(req.Msg.Path())
        if req.Msg.Code() == 2 {
            // We get the path /rd?ep=node1

            if err != nil {
                fmt.Println("TODO send 5.xx: ", err)
            }
            // format the result into link-format
            payload := []byte(rs)

            if _, err := w.Write(payload); err != nil {
                log.Printf("Cannot send response: %v", err)
            }
```

```
Installing github.com/mdempsky/gocode SUCCEEDED
Installing github.com/uudashr/gopkgs/cmd/gopkgs SUCCEEDED
Installing github.com/ramya-rao-a/go-outline SUCCEEDED
Installing github.com/acroca/go-symbols SUCCEEDED
```

master* 2↓ 0↑ ⊗ 2 ⚠ 0 ⓘ 7 go | main.go Thomas Fossati, 24 days ago Ln 11, Col 6 (25 selected) Tab Size: 4 UTF-8 LF Go

Constrained Application Protocol (CoAP)

IETF®

IETF: dozen+ years of IoT standards

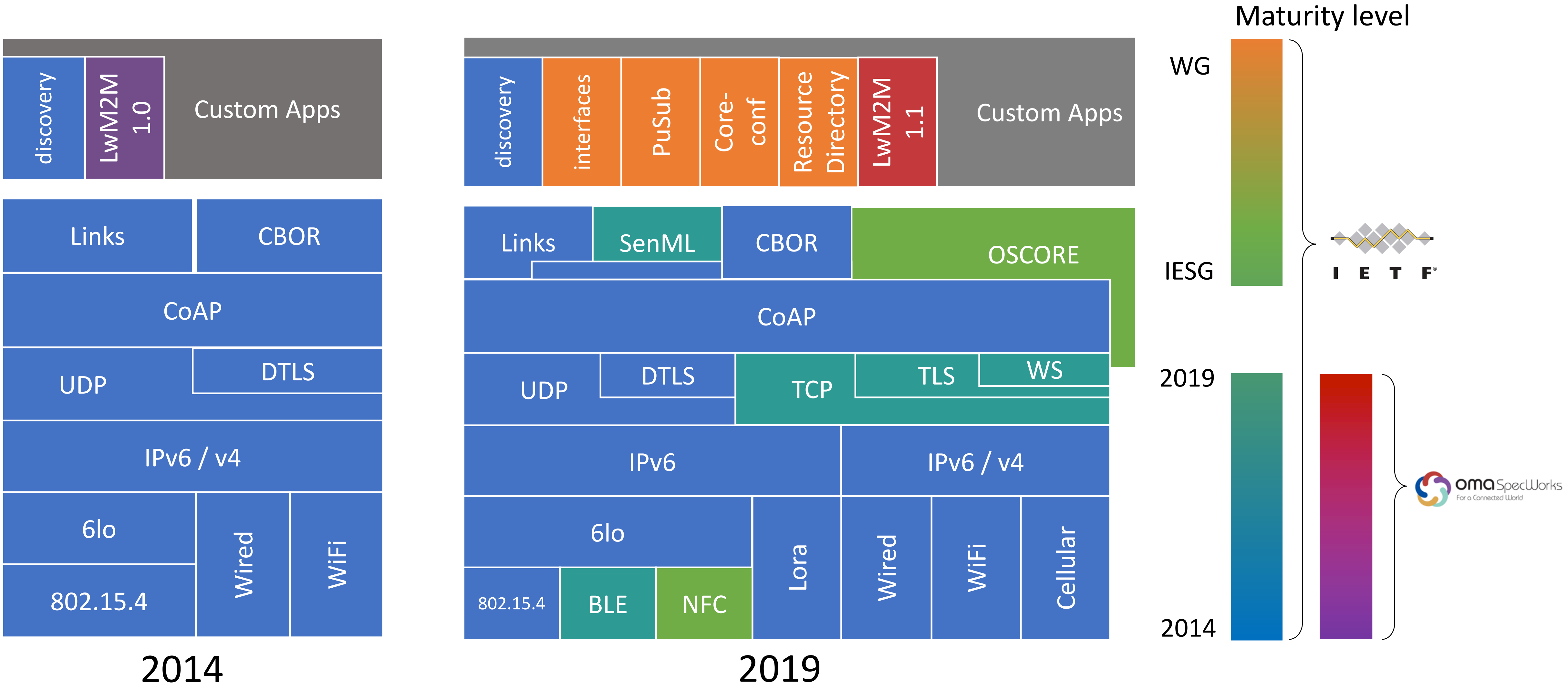
🟧 RFC 2689	🟧 RFC 3485	🟧 RFC 3544	🟧 RFC 3819	🟧 RFC 3940	🟧 RFC 3941	🟧 RFC 4629
🟧 RFC 4919	🟧 RFC 4944	🟧 RFC 5049	🟧 RFC 5401	🟧 RFC 5740	🟧 RFC 5856	🟧 RFC 5857
🟧 RFC 5858	🟧 RFC 6282	🟧 RFC 6469	🟧 RFC 6568	🟧 RFC 6606	🟧 RFC 6775	🟩 RFC 6690
🟩 RFC 7049	🟧 RFC 7228	🟩 RFC 7252	🟧 RFC 7388	🟩 RFC 7390	🟧 RFC 7400	🟩 RFC 7641
🟧 RFC 7668	🟥 RFC 7744	🟥 RFC 7925	🟩 RFC 7959	🟩 RFC 8075	🟩 RFC 8132	🟥 RFC 8152
🟩 RFC 8307	🟩 RFC 8323	🟧 RFC 8376	🟥 RFC 8392	🟩 RFC 8424	🟩 RFC 8516	…and more

🟧 Connectivity WGs

🟩 Application WGs

🟥 Security WGs

Standards Device Stack



Maturity level

discovery
LwM2M 1.0
Custom Apps
Links
CBOR
CoAP
UDP
DTLS
IPv6 / v4
6lo
802.15.4
Wired
WiFi

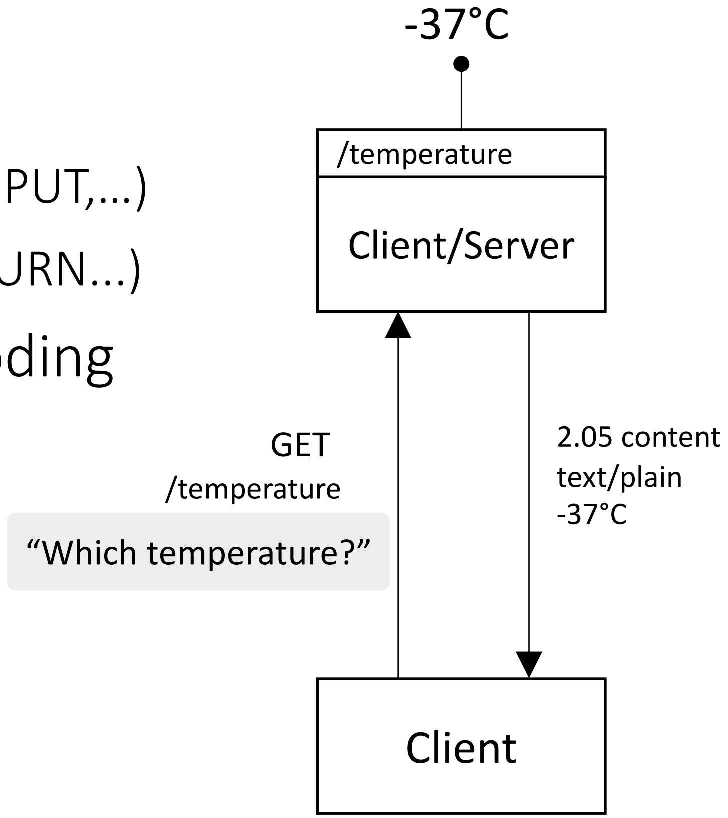
2014

discovery
interfaces
PuSub
Core-conf
Resource Directory
LwM2M 1.1
Custom Apps
Links
SenML
CBOR
OSCORE
CoAP
UDP
DTLS
TCP
TLS
WS
IPv6
IPv6 / v4
6lo
802.15.4
BLE
NFC
Lora
Wired
WiFi
Cellular

2019

The Constrained Application Protocol (CoAP)

- CoAP (RFC7252) implements HTTP’s **REST** model
  - Simple devices: 100 to 250 KiB code and 10 to 50 KiB RAM
  - Each device can be client and server exposing resources
  - CoAP defines methods to access those resources (GET, POST, PUT,…)
  - Same key concepts borrowed from HTTP (Media types, URL, URN...)
- Has a compact 4-byte header, with simple options encoding
- Simple protocol, datagram (UDP, DTLS)
  - Reliability through header message type “*CON/NON*”
  - With TCP/TLS (RFC8323) support for NAT-ed environments
- The Resource Directory provides a directory service



The Constrained Application Protocol (CoAP)

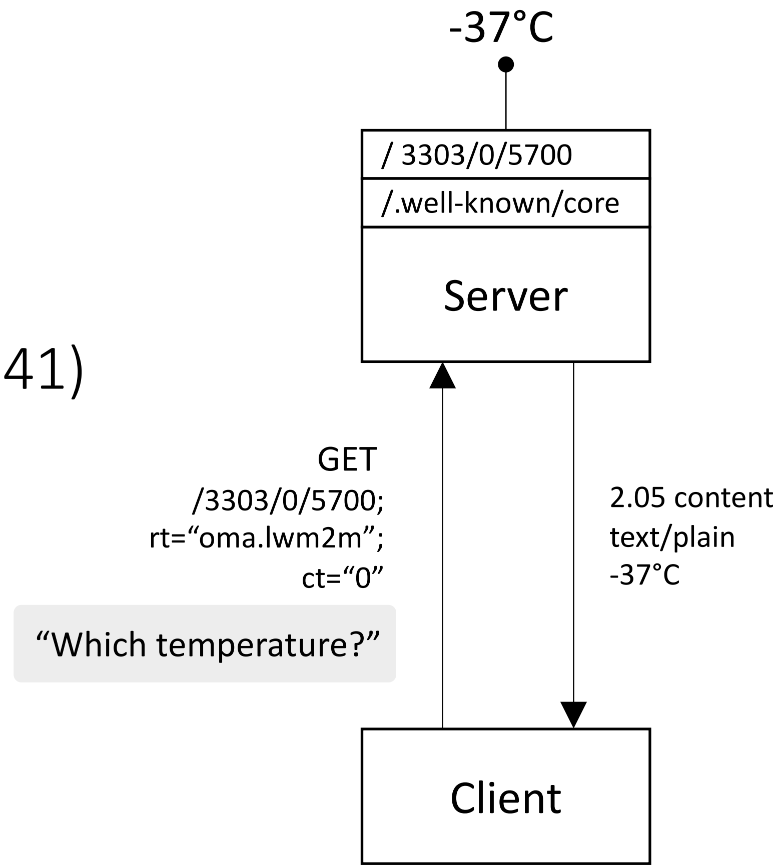
- CoRELink (RFC6690) provides a link format
  - Reuses Web Linking RFC5988 for IoT.
  - Enables query parameters for discovery (lt, gt…)
  - Enables attribute and relation types (rt, if, sz).

```
<3303/0/5700>;rt="oma:lwm2m:temp";ct="0"
```

- Notifications available through *observe* option (RFC7641)
  - Can observe and add query parameters to the observation

```
<3303/0/5700?lt=0>
```

- The *"/.well-known/core"* URI provides discovery
- Multiple serialization formats used with CoAP
  - SenML (RFC8428): Minimalistic JSON
  - CBOR (RFC7049): Binary serialization
- Multiple implementations available at coap.technology

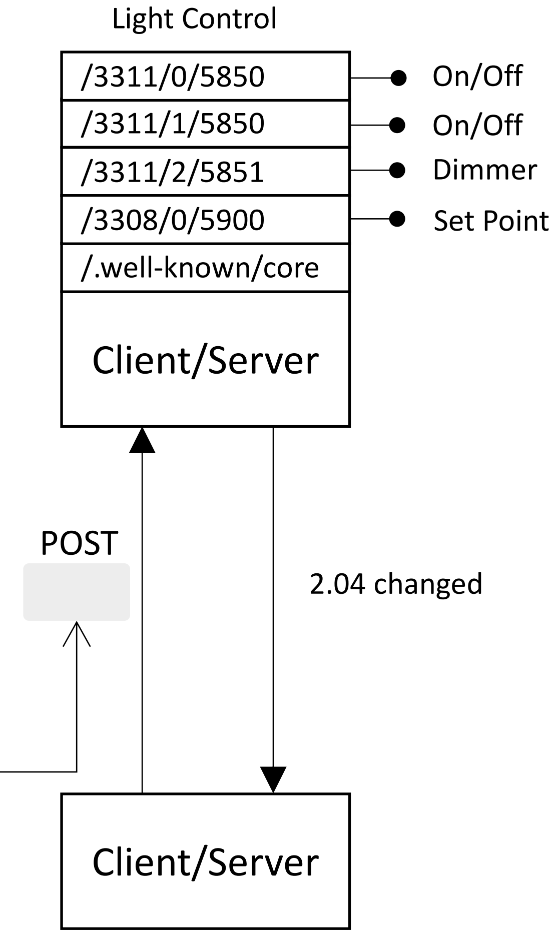


Example Actuation

- When using IPSO actuation is handled with executable (E) resources as well as readable and writeable ones (RW).
  - Parameters needed for actuation are passed along on resources.
  - Type and range of values are known to client based on the schema.
  - Actuation can use executable and writeable (EW) resources.

A server Write-Composite to switch off 2 light sources, dim a 3rd to 20% and set the thermostat to 18 degrees will have a JSON payload as shown in table below. Lights are all controlled by instances of IPSO Light Control Object (Object ID 3311), while thermostat is controlled by an instance of IPSO object Set Point (Object ID 3308).

```
[{"n":"/3311/0/5850", "vb":false},
{"n":"/3311/1/5850", "vb":false},
{"n":"/3311/2/5851", "v":20},
{"n":"/3308/0/5900", "v":18}]
```



Serialization Formats

SenML - JSON

```
[{"bn":"/3/0/","n":"0","vs":"Open
Mobile Alliance"},
{"n":"1","vs":"Lightweight M2M
Client"},
{"n":"2","vs":"345000123"},
{"n":"3","vs":"1.0"},
{"n":"6/0","v":1},
{"n":"6/1","v":5},
{"n":"7/0","v":3800},
{"n":"7/1","v":5000},
{"n":"8/0","v":125},
{"n":"8/1","v":900},
{"n":"9","v":100},
{"n":"10","v":15},
{"n":"11/0","v":0},
{"n":"13","v":1367491215},
{"n":"14","vs":"+02:00"},
{"n":"16","vs":"U"}]
```

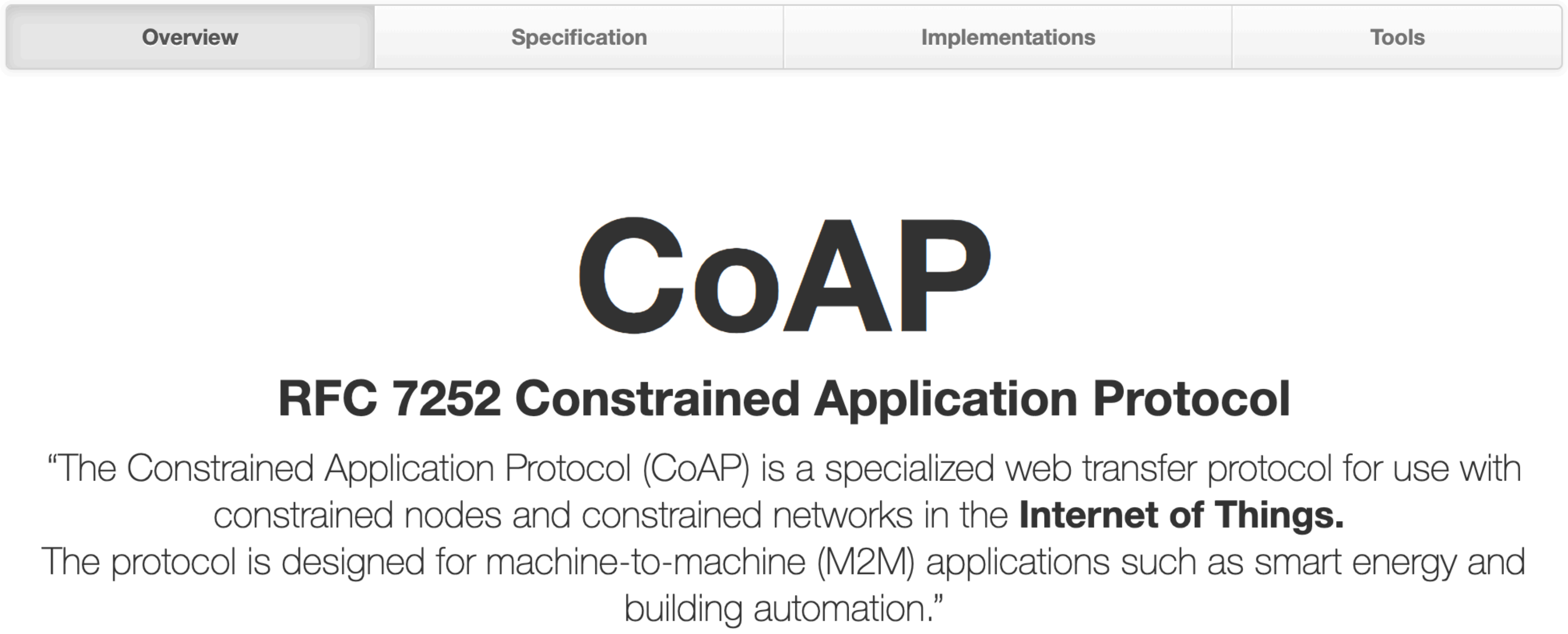
SenML-CBOR

```
90 a3 21 65 2f 33 2f 30 2f 00 61 30
03 74 4f 70 65 6e 20 4d 6f 62 69 6c
65 20 41 6c 6c 69 61 6e 63 65 a2 00
61 31 03 76 4c 69 67 68 74 77 65 69
67 68 74 20 4d 32 4d 20 43 6c 69 65
6e 74 a2 00 61 32 03 69 33 34 35 30
30 30 31 32 33 a2 00 61 33 03 63 31
2e 30 a2 00 63 36 2f 30 02 01 a2 00
63 36 2f 31 02 05 a2 00 63 37 2f 30
02 19 0e d8 a2 00 63 37 2f 31 02 19
13 88 a2 00 63 38 2f 30 02 18 7d a2
00 63 38 2f 31 02 19 03 84 a2 00 61
39 02 18 64 a2 00 62 31 30 02 0f a2
00 64 31 31 2f 30 02 00 a2 00 62 31
33 02 1a 51 82 42 8f a2 00 62 31 34
03 66 2b 30 32 3a 30 30 a2 00 62 31
36 03 61 55
```

SenML-CBOR diagnostic

```
[{-2: "/3/0/", 0: "0", 3: "Open
Mobile Alliance"}, {0: "1", 3:
"Lightweight M2M Client"},
{0: "2", 3: "345000123"},
{0: "3", 3: "1.0"},
{0: "6/0", 2: 1},
{0: "6/1", 2: 5},
{0: "7/0", 2: 3800},
{0: "7/1", 2: 5000},
{0: "8/0", 2: 125},
{0: "8/1", 2: 900},
{0: "9", 2: 100},
{0: "10", 2: 15},
{0: "11/0", 2: 0},
{0: "13", 2: 1367491215},
{0: "14", 3: "+02:00"},
{0: "16", 3: "U"}]
```

CoAP Implementations



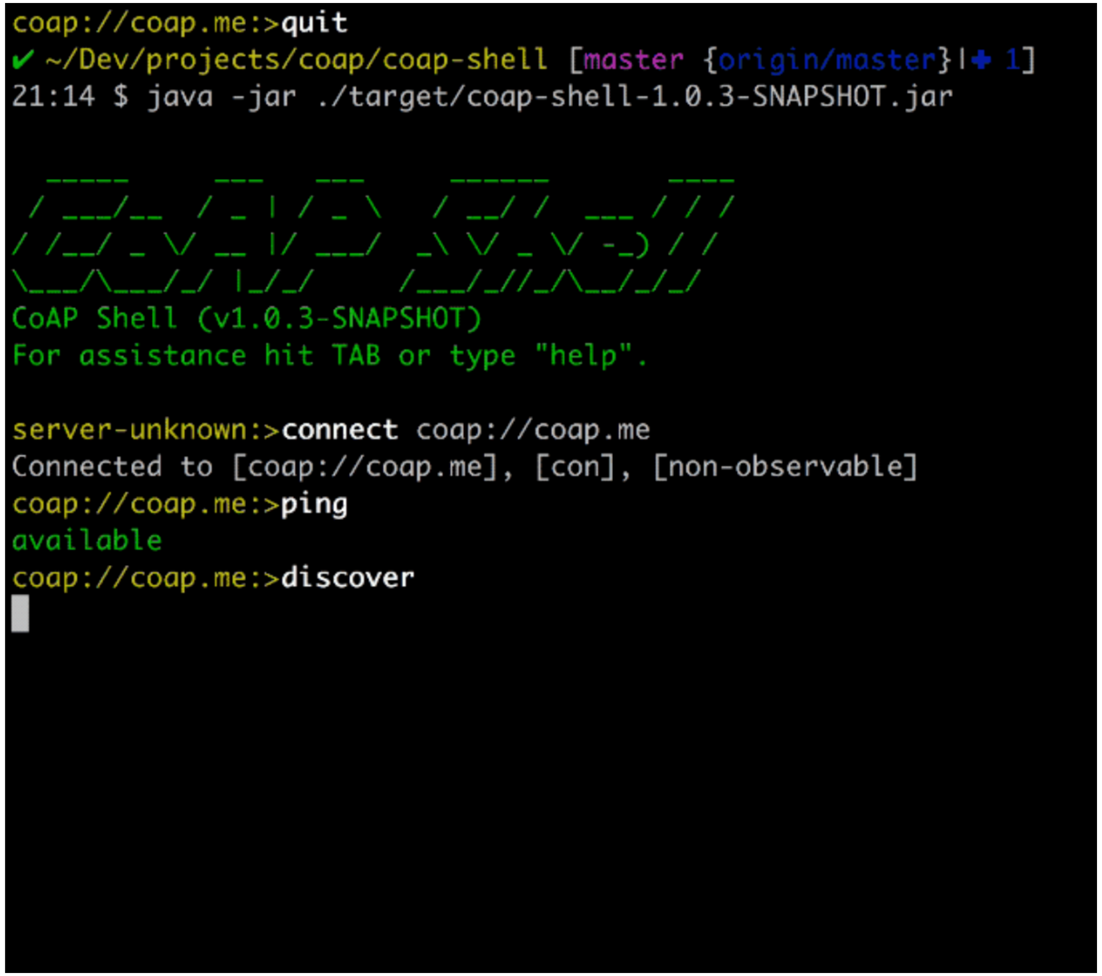
CoAP

RFC 7252 Constrained Application Protocol

“The Constrained Application Protocol (CoAP) is a specialized web transfer protocol for use with constrained nodes and constrained networks in the **Internet of Things.**
The protocol is designed for machine-to-machine (M2M) applications such as smart energy and building automation.”

coap.technology

coap-shell client

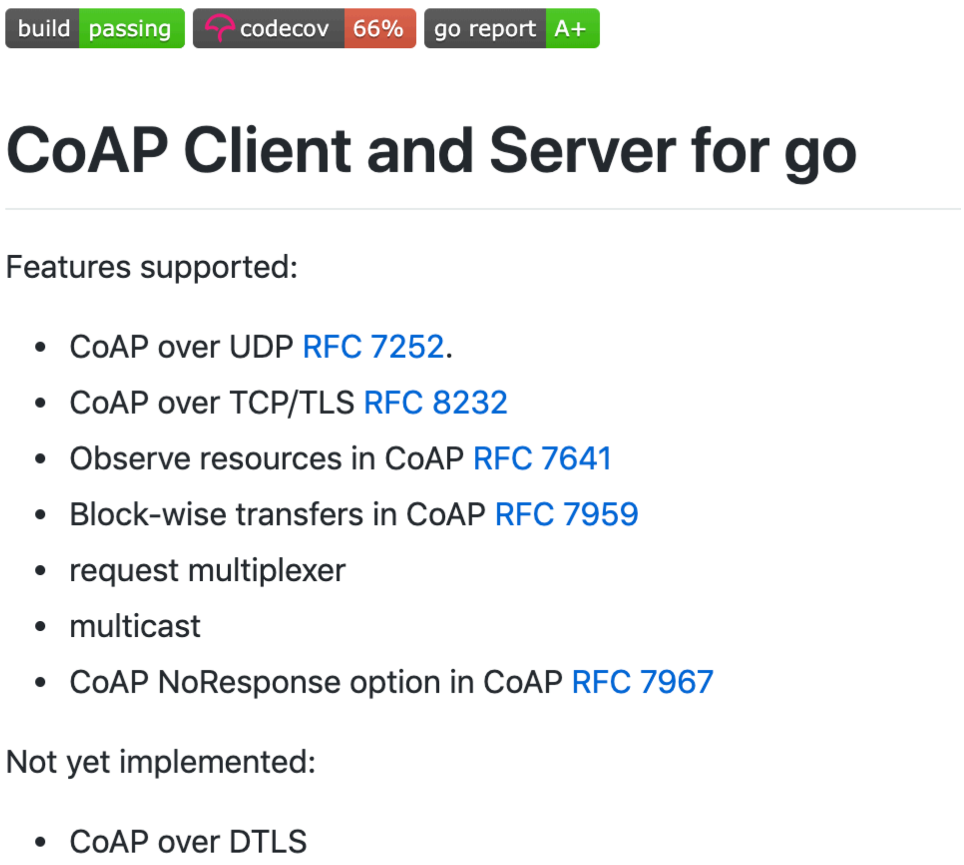


```
coap://coap.me:>quit
✔ ~/Dev/projects/coap/coap-shell [master {origin/master}|✚ 1]
21:14 $ java -jar ./target/coap-shell-1.0.3-SNAPSHOT.jar

  _____     ___   ___    ______       ____
 / ___/__  / _ | / _ \  / __/ /  ___ / / /
/ /__/ _ \/ __ |/ ___/ _\ \/ _ \/ -_) / /
\___/\___/_/ |_/_/    /___/_//_/\__/_/_/
CoAP Shell (v1.0.3-SNAPSHOT)
For assistance hit TAB or type "help".

server-unknown:>connect coap://coap.me
Connected to [coap://coap.me], [con], [non-observable]
coap://coap.me:>ping
available
coap://coap.me:>discover
█
```

github.com/tzolov/coap-shell

https://asciinema.org/a/wPnbU56v1R3nkMafnmzaiB20B

go–coap server + coap-shell client



build passing | codecov 66% | go report A+

CoAP Client and Server for go

Features supported:

- CoAP over UDP RFC 7252.
- CoAP over TCP/TLS RFC 8232
- Observe resources in CoAP RFC 7641
- Block-wise transfers in CoAP RFC 7959
- request multiplexer
- multicast
- CoAP NoResponse option in CoAP RFC 7967

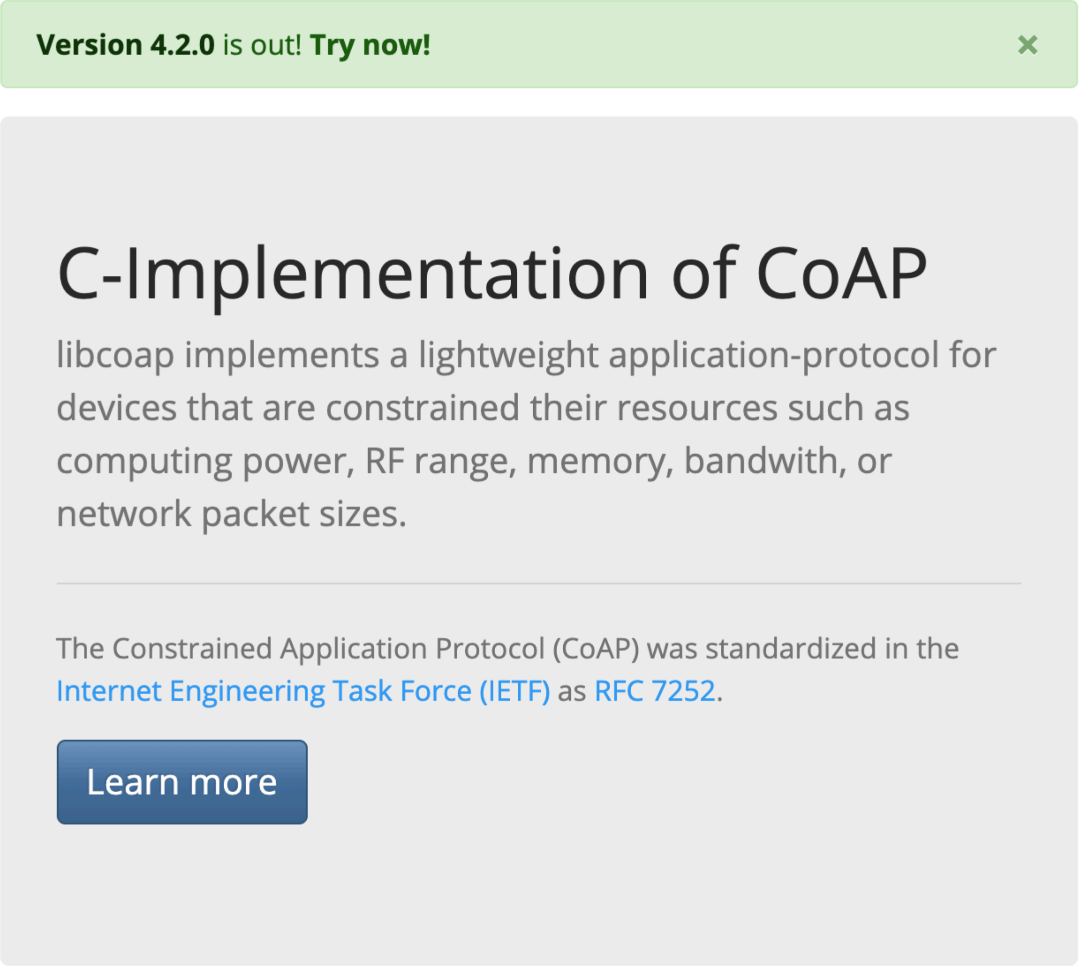
Not yet implemented:

- CoAP over DTLS

github.com/go-ocf/go-coap

https://asciinema.org/a/tAFMptkzA86KU9OQMqhswDCTa

Libcoap client and server



Version 4.2.0 is out! **Try now!**

C-Implementation of CoAP

libcoap implements a lightweight application-protocol for devices that are constrained their resources such as computing power, RF range, memory, bandwith, or network packet sizes.

The Constrained Application Protocol (CoAP) was standardized in the Internet Engineering Task Force (IETF) as RFC 7252.

github.com/obgm/libcoap

https://asciinema.org/a/I0yOK7e5qgMOQmXYmBUqp1Vbr